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Innovations in United States Marine Corps Expeditionary Power Systems

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The United States Marine Corps (USMC) brings unique capabilities to all missions and fulfills a key role as part of any joint operation. To enable these mission capabilities, however, new or upgraded equipment is often required. With each equipment upgrade there is an increase in demand for deployable, quality electric power to support mobile and base operations. Military power systems must be capable of rapid deployment and thus transportable on a host of air, land, sea, and sub-surface platforms. These power systems must also be able to generate and distribute the required quantity and quality of power while being exposed to a wide variety of climates, terrains, temperatures, altitudes, and corrosive environments. Finally, to support the current engagement and to be ready to support the next engagement, these systems must be rugged, maintainable, sustainable, reliable, and efficient.

The Marine Corps Systems Command (MARCORSYSCOM) is the Marine Corps Commandant's principal agent for acquisition and sustainment of systems and equipment used by the Operating Forces to accomplish their warfighting mission. Within MARCORSYSCOM are 27 Program Management Offices, each with a focus on their unique commodity assignment (e.g., weapons, clothing, communications, tanks, etc.). The Program Manager for Expeditionary Power Systems (PM EPS) is responsible for research, development, acquisition, and life cycle management of all power systems for Marine Corps ground forces, which includes tactical power generation, power distribution systems, battery management and sustainment, alternative power systems, container systems, and environmental control systems. The Program Manager works closely with other services for joint solutions, which often can be leveraged to the Corps' advantage. However, when unique missions or capability gaps exist, MARCORSYSCOM has not been adverse to embark upon and capture the opportunity for innovative solutions.

This article provides an overview of some of the innovative efforts that are taking place at MARCORSYSCOM to support the warfighter while providing for the growing need of reliable and robust sources of electric power. The article covers mobile electric power, advanced power sources, renewable energy systems, and onboard vehicle power.

MOBILE ELECTRIC POWER

The requirement for tactical electric power is an enduring need that is and will continue to be a critical enabler for all forces. A family of Mobile Electric Power (MEP) systems and components supports the full range of USMC missions, including air control, communication/information systems, environmental control systems, and life support systems in addition to the general power requirements of operating forces.

The Marine Corps' strength in innovation was recently demonstrated while meeting a unique demand for units deploying during Operation Iraqi Freedom (OIF). These forces needed a trailer-mounted generator and environmental control unit (ECU) that could be towed behind a High Mobility Multi-purpose Wheeled Vehicle (HMMWV) to support the Regimental Commanders' Unit Operations Center (UOC). Traditional tactics and the size and weight of existing equipment would normally place generators and ECUs on tactical transport trucks and trailers buried within the logistics lines of combat service support, but the UOC needed to be at the forefront of the maneuver element in the new, highly maneuverable, digitally networked, combat environment.

An Integrated Trailer-ECU-Generator (ITEG) assembly was developed for the Marine Corps utilizing commercial components that were integrated into a single platform. The ITEG,

Figure 1. Integrated trailer-environmental control unit-generator.

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14. ABSTRACT

The United States Marine Corps (USMC) brings unique capabilities to all missions and fulfills a key role as part of any joint operation. To enable these mission capabilities, however, new or upgraded equipment is often required. With each equipment upgrade there is an increase in demand for deployable, quality electric power to support mobile and base operations. Military power systems must be capable of rapid deployment and thus transportable on a host of air, land, sea, and sub-surface platforms. These power systems must also be able to generate and distribute the required quantity and quality of power while being exposed to a wide variety of climates, terrains, temperatures, altitudes, and corrosive environments. Finally, to support the current engagement and to be ready to support the next engagement, these systems must be rugged, maintainable, sustainable, reliable, and efficient.

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shown in Figure 1, performed as required and has since been adopted by many other operating units, including supporting command posts, medical units, and intelligence organizations.

A drawback to the arrangement of the ITEG is the inefficiency of the component interfaces. For example, the diesel generator converts chemical energy (diesel fuel) into mechanical energy (via the engine), which drives an alternator to generate electric power. Two-thirds of this electric power is used to drive an electric motor in the ECU, which powers a compressor as part of a vapor cycle cooling loop to generate air conditioning in high temperature conditions. During cold ambient temperature conditions, the generator's electric power is sent to electrical resistive heating elements to generate heat.

All components of the ITEG performed as required. However, since ITEGs are a key enabler for highly maneuverable units and are now employed and embedded across all USMC communities, improvements to the system were investigated as part of developing the next generation system. An improved ITEG, (see Figure 2), with a simplified design and increased efficiency has been developed and is in testing. Efficiency was improved by removing the mechanical-to-electrical-to-mechanical conversion process from the old system and by using the engine flywheel to directly drive the vapor cycle compressor. This resulted in a 20% efficiency improvement to the new system. The diesel generator was replaced with a permanent magnet generator to provide a threefold increase in usable electric output power. In addition, the new system can harvest the heat from the engine coolant for conditioned air heating instead of allowing it to escape to the atmosphere as it did in the first generation system. A collective protection over-pressure system was also added to enable continued operation in Nuclear, Biological and Chemical (NBC) environments, which was not possible with the previous system.

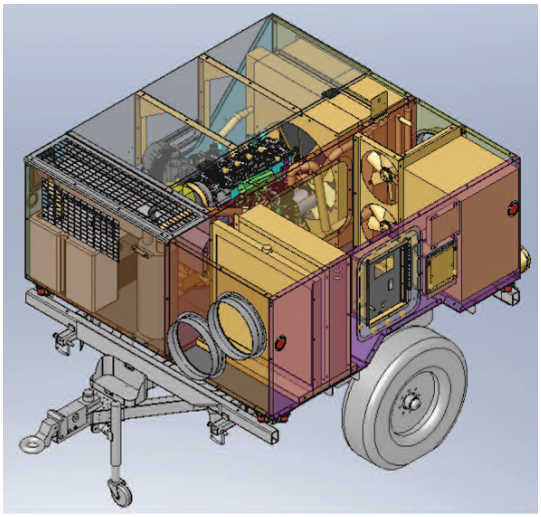

Figure 2. Improved integrated trailer-environmental control unit generator.

The system integrator* is accelerating the development of this product to address not just military needs but also the commercial rental market, which also requires air conditioning and electrical power in remote sites (e.g., work sites, conventions and exhibitions, party rental tents, etc.). The NBC over-pressure functionality will be on military units only.

Mobile Electric Power DIStribution

In addition to power generation, a key component of MEP is power distribution. A near-term ramification of operations in Afghanistan and Iraq, as well as other Marine deployments, was a lack of Mobile Electric Power DIStribution (MEPDIS) sets, including power distribution panels and wiring harnesses. An acquisition decision to move toward commercial-based power distribution systems has resulted in a tailorable family of components that are lighter, cheaper, and faster to produce. Market research highlighted that the power distribution needs of the commercial entertainment and rental industries were highly analogous to those of the USMC. These industries support functions (e.g., concerts, work sites, stage shows, carnivals, etc.) that require equipment which can be rapidly set up and disassembled, and are operable in all weather conditions, durable during rough handling, and highly supportable and maintainable with minimal training; these are the same capabilities the Marine Corps requires.

Another key aspect of the USMC MEPDIS replacement system was the transition from military unique electrical connectors to commercial-based connectors and electrical standards. Originally implemented in the 1980's, military specific connectors were the only components robust enough for harsh environments. During the ensuing period, commercial connectors in accordance with International Electrotechnical Commission (IEC) standards have been developed and proven to fully meet rigorous military requirements. Whereas unique military connectors can sometimes have up to a six-month lead-time for delivery, commercial connectors are available worldwide and routinely stocked for immediate point-of-sale transaction. The Program Manager conducted a user evaluation of different electrical connector types and styles with Marine Corps electricians to achieve buy-in of the acquisition strategy and configuration changeover. Utilizing available commercial and military data, user input, and commercial standards, a commercial item acquisition approach was put in place, which was well received by industry.

Six new USMC power distribution panels, shown in Figure 3, were fielded. These panels are robust, tolerant, and capable of withstanding harsh environments and rough handling. A key feature of the new system was reduced weight, lower life cycle cost, and improved time of delivery. Polyethylene cases made from recycled plastic reduce weight by 33% while providing electrical insulation.

Although commercial-based, all articles have undergone and successfully passed verification testing for military test protocols. The smaller panels have also received third-party certification for electrical safety and handling.

Throughout the program, managing risk and maintaining high safety standards has been paramount. Components have multiple safety systems and interlocks to protect users from electrical hazards. These features have been verified in both technical testing and operational deployments with Marine Corps units. Cost savings of 40-65% per component have been realized with the commercial item strategy. The MEPDIS replacement program has been a hallmark program in innovative contracting, program management, testing, and risk mitigation, and it was recognized in 2007 with the DoD "David Packard Excellence In Acquisition Award."

ADVANCED POWER SOURCES

As a significant user of military batteries to power a large number of weapons, sensors, and communications systems, the USMC was severely impacted in 2003 by the military battery shortage experienced during the early phase of OIF. Analogous to the initiatives intended to improve the "big power" systems of the MEP family, the USMC Advanced Power Sources (APS)

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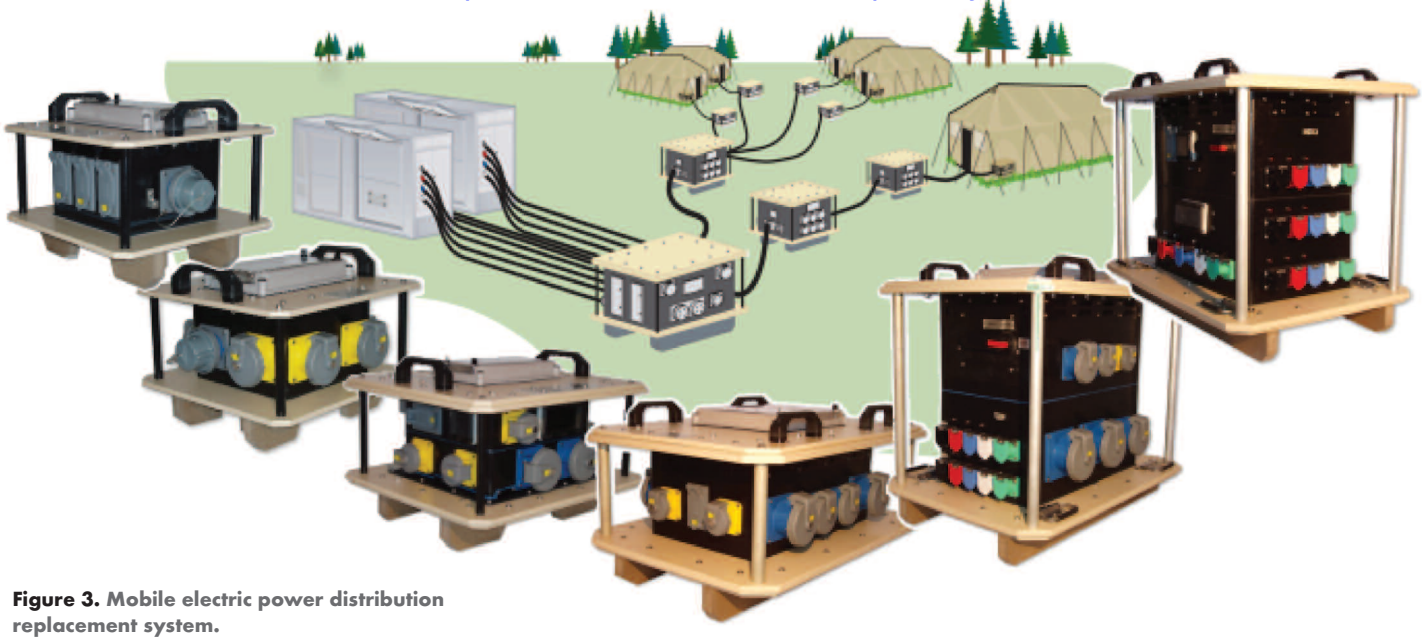

Figure 3. **Mobile electric power distribution replacement system.**

program is focused on the small power realm in part to improve logistic flexibility.

The APS program provides a suite of devices with power in the range of 20 watts to 2 kilowatts (kW) for energizing communications equipment, computers, and other peripheral equipment in mobile, tactical, or remote environments. These devices provide battlefield commanders with options and flexibility, while leveraging commercial solutions to the maximum extent possible for cost and logistic reasons. Key focus areas of the program that have already shown an ability to decrease the Marine Corps' logistical footprint include: battery management systems, adoption of rechargeable batteries, power adaptors for units in garrison operations, renewable energy systems, and onboard vehicle power systems.

During OIF, battery users had no means of determining the remaining amount of charge in their batteries prior to the start of a mission. To remove the risk of a battery dying at a critical point in a mission, warfighters would install a fresh battery every day or every mission. This created a battery shortage and also resulted in piles of discarded batteries that were not entirely expended. Working with the US Army, the USMC has introduced one-time use military batteries with built-in State of Charge Indicators (SOCI) to help manage inventories and usage. In addition, similar to what is occurring in the commercial sector, military use of rechargeable batteries is increasing. With advanced lithium-ion battery technology close to matching the energy densities of disposable batteries, more rechargeable batteries are being used by operating forces.

Although weapons and communications systems are typically designed to be highly mobile, often this same equipment is used at bases and stationary locations where host power is available. In these situations, radio power adaptors enable the use of 120/240 volts alternating current (VAC) which provides a means to conserve critical battery stockpiles. While other services allow the purchase of adaptors or support equipment with unit funds, in favor of commonality the USMC decided to centrally manage, fund, and field standard equipment. Numerous suppliers make and sell items to support military equipment, but not all items are created equal. The USMC has established an evaluation and vetting process for electronics equipment and routinely fields several new classes of equipment each year as new radios or communications devices hit the fleet. As part of a formal solicitation process to industry, the USMC provides a set of technical and verification requirements for the needed capability. The USMC will then request bailment (no-cost) copies of the article from all suppliers, which are then taken to an independent test laboratory for verification (USMC pays for testing). In exchange for loaning the article, the supplier is provided a complimentary copy of the test results for their equipment item. From testing the USMC obtains validated data to support the formal source selection process for procuring and fielding the equipment. This process has worked with great success for several reasons. The government is able to collect sufficient quality information on which a well-informed selection decision can be made. The process is transparent to industry, and the participating suppliers receive independent test data of their product in exchange for temporary loan of the equipment.

RENEWABLE ENERGY SYSTEMS

In 2006, the Commanding General for Multi-National Forces in Iraq submitted a Joint Urgent Resource Request (JURR) for renewable energy systems. The basis of the need was principally to seek relief for the numerous fuel convoys that were prime insurgent targets, but there was also a need at the operator level for more responsive power solutions for a wide range of mission equipment in austere and remote sites. Lighting, surveillance equipment, and sensor arrays need continual power, but the power requirements do not typically constitute a need for a generator. This equipment, however, is too large for most battery systems and is typically too remotely located to draw from grid power sources. The JURR requested a family of small, medium, and large power systems. In response, the USMC, with support from the Office of Naval Research (ONR), embarked upon a development and demonstration program of a HMMWV towable trailer mounted system (less than 3000 pounds total system weight) that can produce between three to five kW of electric power (analogous to the power need at a small forward operation post). Utilizing commercial components for energy

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Figure 4. Man-portable renewable energy system.

collection (wind and solar), energy storage (lead acid and lithium-ion batteries), and electronic control, three different systems were initially designed, and then two systems were fabricated and tested. Testing is still ongoing, but preliminary lessons learned to date include:

- Wind power generation equipment is too heavy and not effective for small, highly mobile units
- Solar panel selection is critical, with efficiency versus weight versus robustness being key drivers
- The footprint of solar panels is extensive
- For a 24-hour duty cycle where multiple kilowatts of power is needed, the system will require either a large quantity of lithium-ion batteries or a diesel generator for nighttime operation
- Use of lithium-ion batteries is a significant system cost driver (approximately 30-40% of system cost)
- Production systems in this power range cost 20-30 times that of a diesel generator

On a smaller scale, such as a man-portable renewable energy system, (see Figure 4), the USMC is now conducting user evaluations on two systems that weigh less than ten pounds and can be easily folded up for transport.

Targeted for a specific function (charging a battery for a radio system or directly powering a radio power adaptor) and for specific equipment, these smaller systems have the flexibility to support niche missions. These systems are being evaluated to determine if they can be set up and operated together to support larger power loads. Similar to the commercial sector, renewable energy systems are still in their infancy in the military, and they require more evaluation and understanding to determine where and how they can be used to their maximum potential.

ONBOARD VEHICLE POWER

Currently, man-portable and trailer-mounted generators fill the bulk of power generation requirements for tactical electric power. However, towing a trailer limits the vehicle's payload capacity, restricts mobility, and consumes critical embarkation space when Marine Expeditionary Units deploy via an aircraft transport or aboard naval amphibious shipping. Moreover, with the continued addition of more electronic warfare systems, communications systems, situational awareness devices, and electrically powered accessories on tactical vehicles, the vehicles are running out of electric power. Shown in Figure 5 is the historical trend of installed electric power on the two most prolific vehicles in the USMC combat inventory: the HMMWV and the Mine Resistant Ambush Protected (MRAP) vehicle.

Two initiatives intended to get ahead of the "power curve" and to address future onboard vehicle power systems in tactical vehicles are under development by ONR and transitioning to MARCORSYSCOM in 2009. The first vehicle development and demonstration has been on the HMMWV (see Figure 6) for a capability of 20-30 kW of onboard and exportable power. This level of electric power follows historical trends for power demands in Command and Control intensive applications, while also enabling enhanced capabilities unseen with any vehicle today. In addition to directly powering onboard systems, the vehicle can serve as a temporary power generation system for an Operations Center, a back-up generator for any application, an uninterruptible power supply for mission critical equipment, and as a direct power source for power hungry, vehicle mounted mission equipment that normally would have a towed generator as its power source. As of the time this article was being printed, the prototype vehicle was to be delivered to the US Army Aberdeen Test Center (ATC) for test and evaluation. It is the intention that this capability will begin initial production and fielding in 2010 as a mission role variant of the HMMWV for the USMC.

Also coming out of the science and technology arm of ONR is an even greater level of capability on a larger platform. On the USMC Medium Tactical Vehicle Replacement (MTVR), shown in Figure 7, will be a retrofit kit that replaces the current mechanical transmission with a diesel-electric transmission.

Similar to locomotive power systems, the under-hood diesel engine of the MVTR directly powers a large alternator. All mechanical power from the engine is converted to electrical power, which is then used to drive electric motors that power the unaltered driveline of the MTVR. But the unique attribute of this system is the ability to tap the electric power distribution system

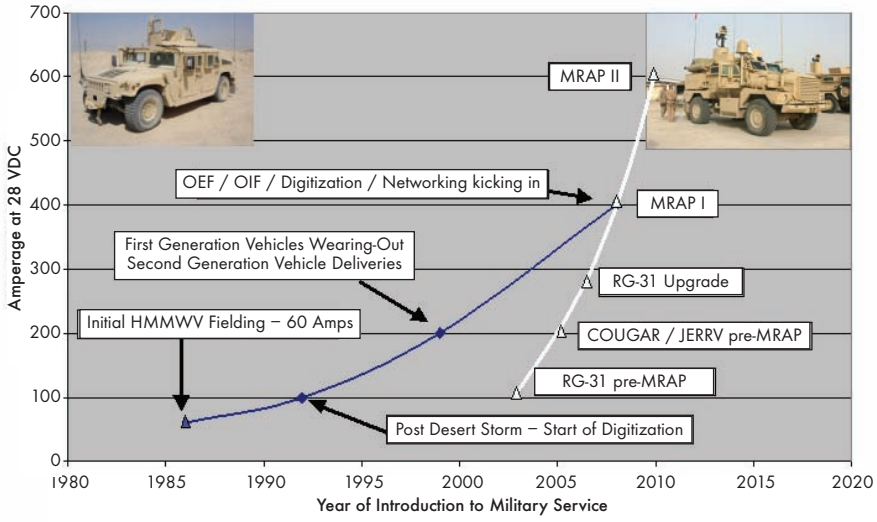

Figure 5. Installed vehicle electric power capability.

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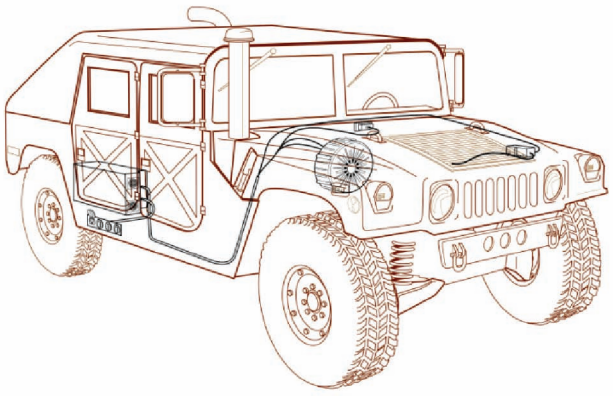

Figure 6. HMMWV onboard vehicle power system.

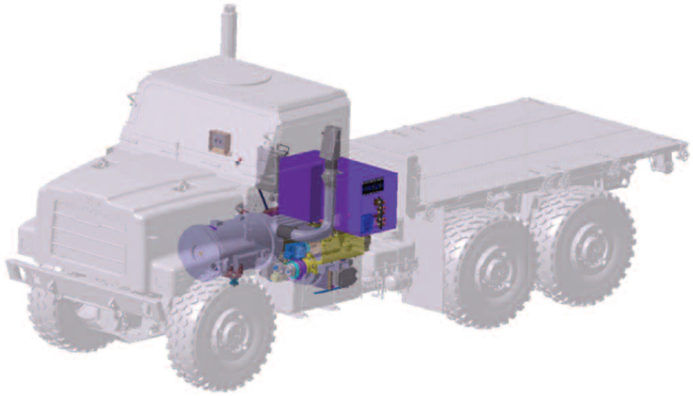

Figure 7. MTVR onboard vehicle power system.

to power both onboard and off-board systems. In this vehicle application, the first prototype system has demonstrated in testing at ATC up to 120 kW of exportable electric power while the truck is stationary and up to 21 kW of onboard electric power while the truck is on the move. Similar to the HMMWV, this system will be ready for production and fielding in 2010 as a mission role variant.

SUMMARY

In its role to support the operating forces of the USMC, the Program Manager for Expeditionary Power Systems continues to develop, field, and support a wide range of power solutions. Realizing that no one solution fits all needs, the Program Management Office attempts to offer power solutions with a menu of choices. In addition, as new tactics and missions evolve so, too, must solutions and opportunities. Innovative alternatives continue to be a hallmark of the United States Marine Corps and MARCORSYSCOM.

Additional information and reference material for the whole family of USMC power systems is available at http://www.marcorsyscom.usmc.mil/sites/pmeps.

NOTE

* Magnum Products LLC of Berlin, Wisconsin

Mr. Michael A. Gallagher is the Program Manager for Expeditionary Power Systems at the Marine Corps Systems Command, Quantico, Virginia. Within Expeditionary Power Systems, the organization is responsible for research, development, acquisition, and life cycle management of numerous power systems for the Marine Corps, including tactical power generation, power distribution systems, battery management and sustainment, alternative power systems, environmental control systems, and container systems. Mr. Gallagher's background and 30 years of acquisition experience have focused on numerous Marine Corps Ground Combat Systems, Combat Support Systems, and Naval Amphibious Systems.

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